From fossil-based refinery to biorefinery – stepwise implementation of integrative plant concepts

Lichtenwalde, May, 12th 2011

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Biotechnology Plants
Linde-KCA-Dresden GmbH

Agenda

The Linde Group

— Linde-KCA-Dresden GmbH – competence center BIOTECHNOLOGY

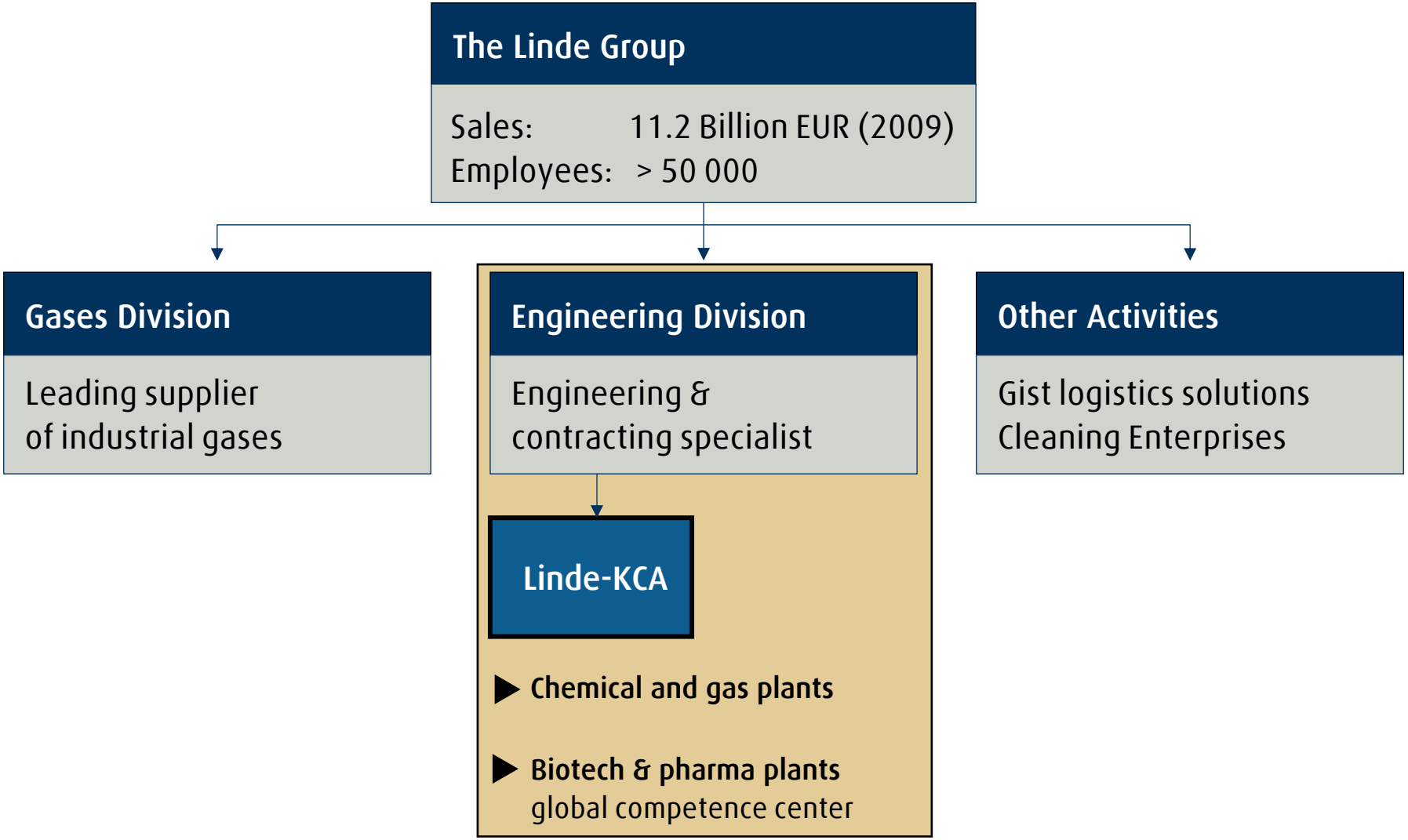
The Linde Involvement in Process Implementation

From TODAY's chemical sites to FUTURE integrated bio/chem sites – Leuna as an example

— **The CBP Leuna**
  — Motivation
  — Structure and Location
— **A promising example: Bio-Ethylene for Biorefinery**
  — Economic figures and targets
  — Perspective for implementation in Leuna
— **"Green" H2 in Leuna**
  — Hydrogen via Pyro-reforming of Glycerol: a new Linde Pilot-plant in Leuna

Conclusion & Outlook

Linde-KCA is Part of The Linde Group



Linde-KCA – Company Overview

HQ in Dresden, Germany

Sales: approx. 250 million €, Employees: approx. 500

Linde-KCA – Global Competence Center Biotechnology

Biotechnology Plants (B)

- Biotechnology
  - process technology
  - extensive know-how
- design & construction of large-scale biotech plants
- process technology fine chemistry

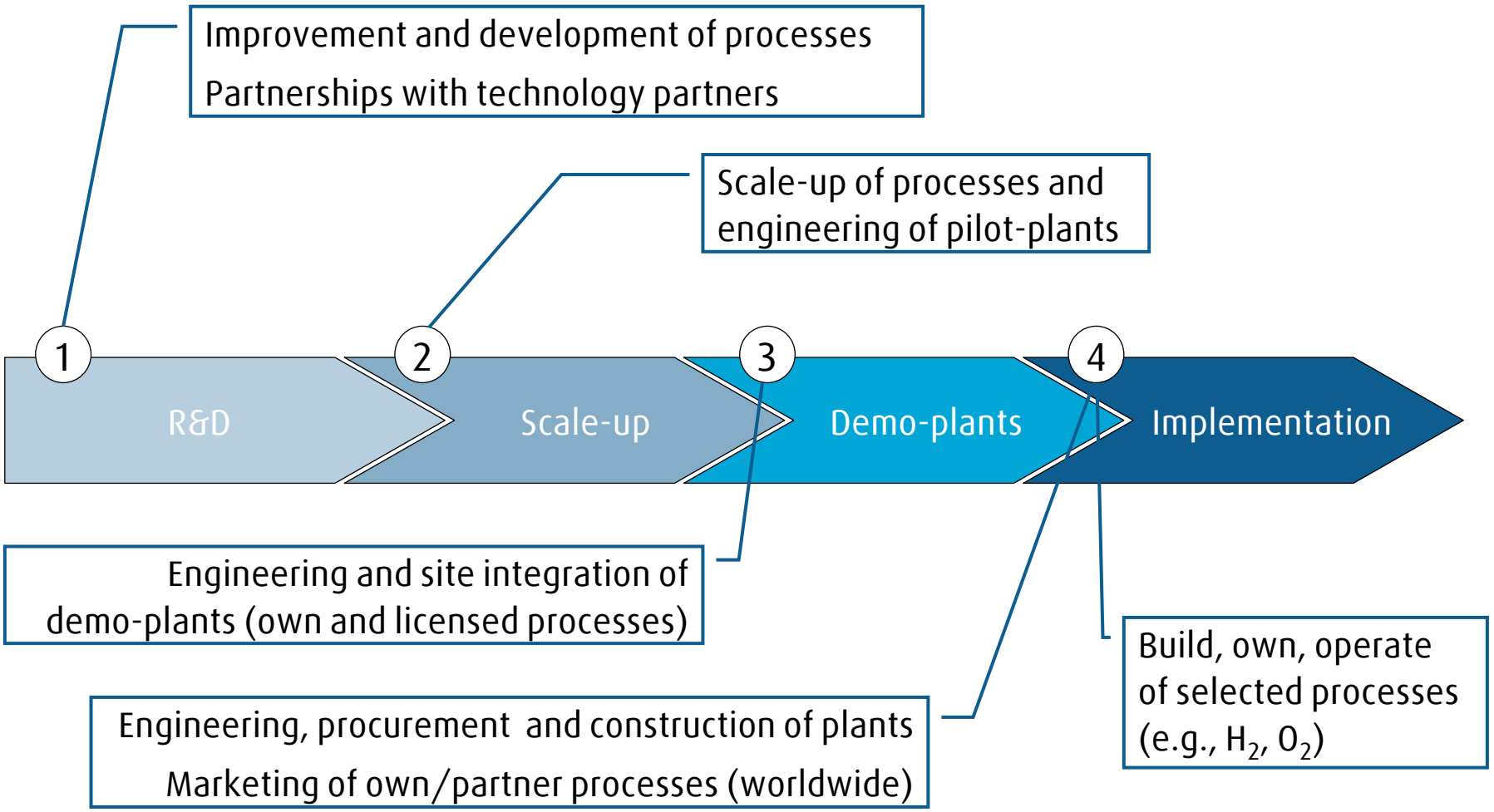
Chemical and Gas Plants (C)

- Chemistry
  - own and licensed processes
  - process technology
  - extensive know-how
- design & construction of large-scale chemical plants

Synergistic cooperation of divisions — Integration of biotechnology & chemistry

„Key to Success“ for Industrial Biotech/Biorefinery Projects

The Linde Involvement in Process Implementation



Plant for the Production of Modified Wheat Starch and Gluten

Client
FRP CS GmbH

Location
Zeitz / Germany

Type of plant
Plant for Production of
modified wheat starch and gluten

Scope of Work
Conceptual Design,
General contractor technology *)
(Engineering, Procurement,
Construction, Commissioning)

Project Period
2006 – 2009

*) in consortium with firm KAEFER Construction GmbH
as general contractor building

Pilot Plant for the Production of 2G Biofuels – Enzymatic Route

Client
Süd-Chemie AG

Location
Munich / Germany

Type of plant
Pilot plant for the production of Biofuels (2nd Generation) from cellulosic raw materials

Scope
Concept Design,
Basic and Detail Engineering,
Procurement, Installation,
Supervision of Commissioning

Start-up
2009

Linear alpha Olefin Plant

Client & development partner
United Petrochemical Company

Location
United Olefins Complex in Al-Jubail/Saudi Arabia

Process
Sabic Linde "α-Sablin" Process

Capacity
150 000 t/a α-Olefine

Process steps
Feedstock and catalyst handling, reaction and catalyst removal, primary separation, product separation

Scope of work
Turnkey lump sum: Detail engineering, procurement, construction, precommissioning, commissioning support

Start-up
2006

Polyethylene Plant

Client
Eastern Petrochemical Company (SHARQ)

Location
Al-Jubail/Saudi Arabia

Process
PE process licensed by SABIC

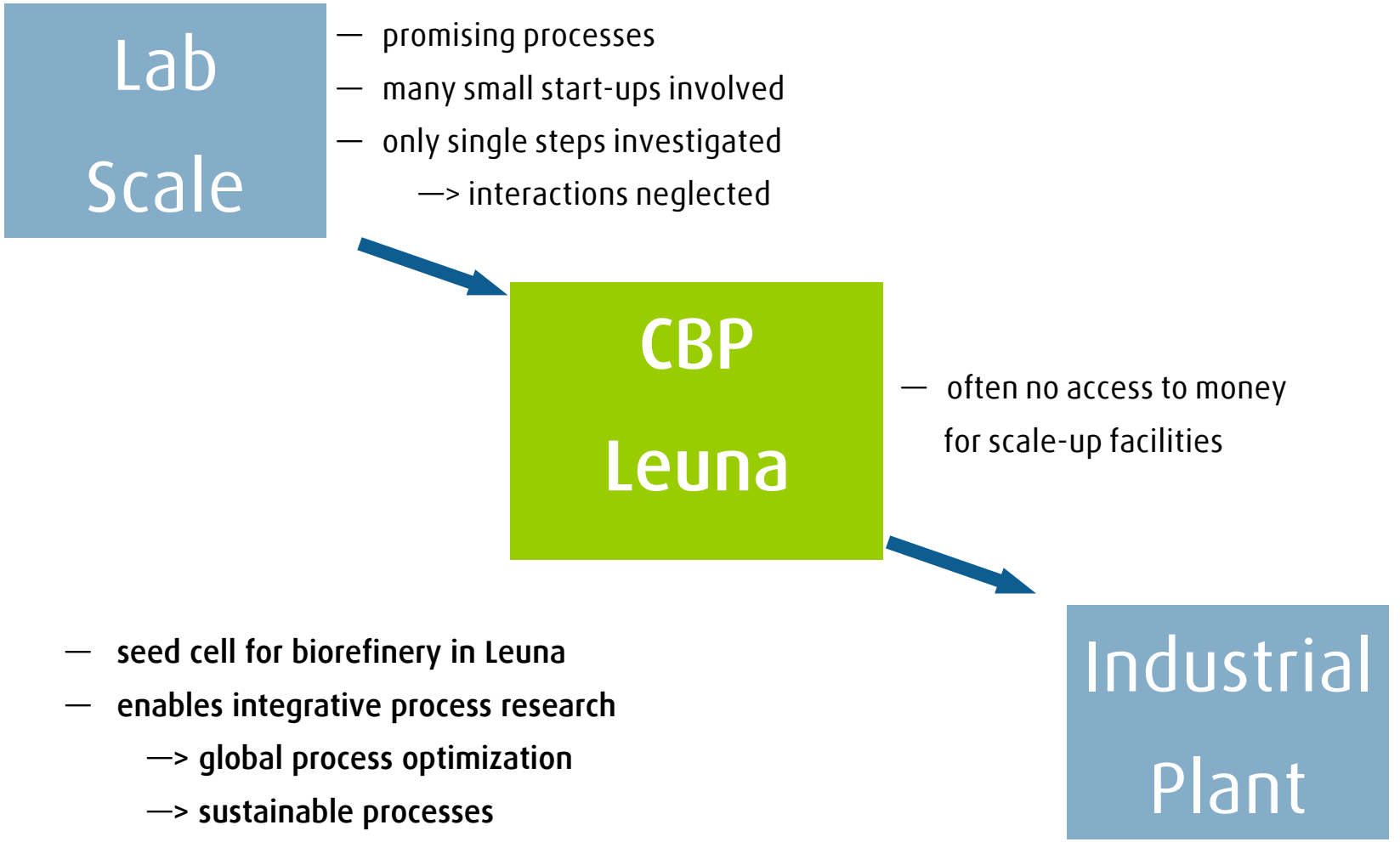
Capacity
800 000 t/a HDPE and LLDPE

Process Section
Raw material purification, catalyst preparation, polymerization, additive handling, pelleting, vent recovery, pellet blending and storage, bagging and palletizing, bulk loading

Scope of Work
Turnkey lump-sum

Start-up
2009

Process Development in White Biotech based on Renewables



Biorefinery Leuna – CBP
Fraunhofer Center for Chemical-Biotechnological Processes

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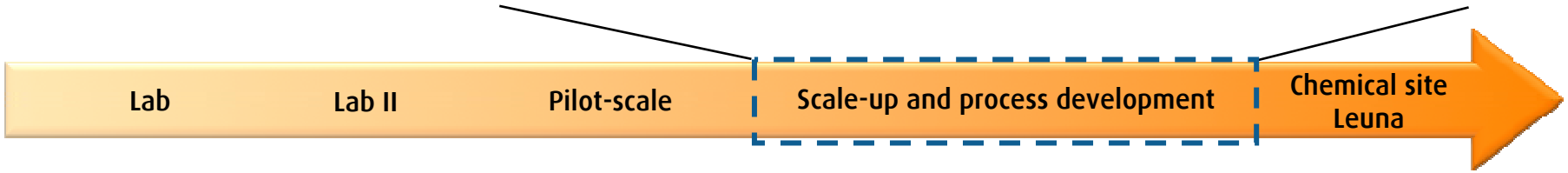
At the new Fraunhofer CBP in Leuna state-of-the-art facilities will be available for the development and scale-up of industrial biotech processes

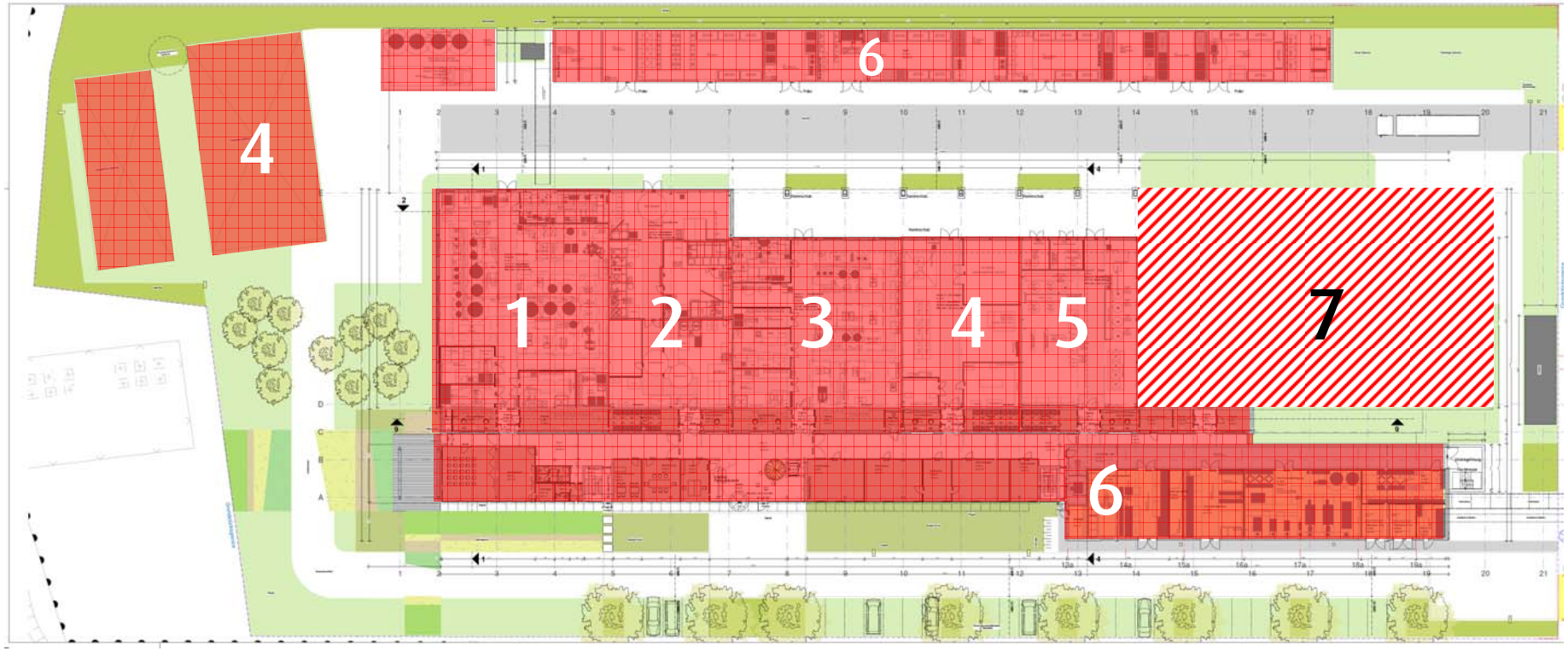
- > 8.000 m² total space
- 25 L to 10.000 L process volume
- various USP & DSP
- feedstock flexibility
- integrative processes
- 5 individual modules

→ **Linde-KCA rewarded as general contractor technology**

→ **Linde-KCA involved as R&D partner**

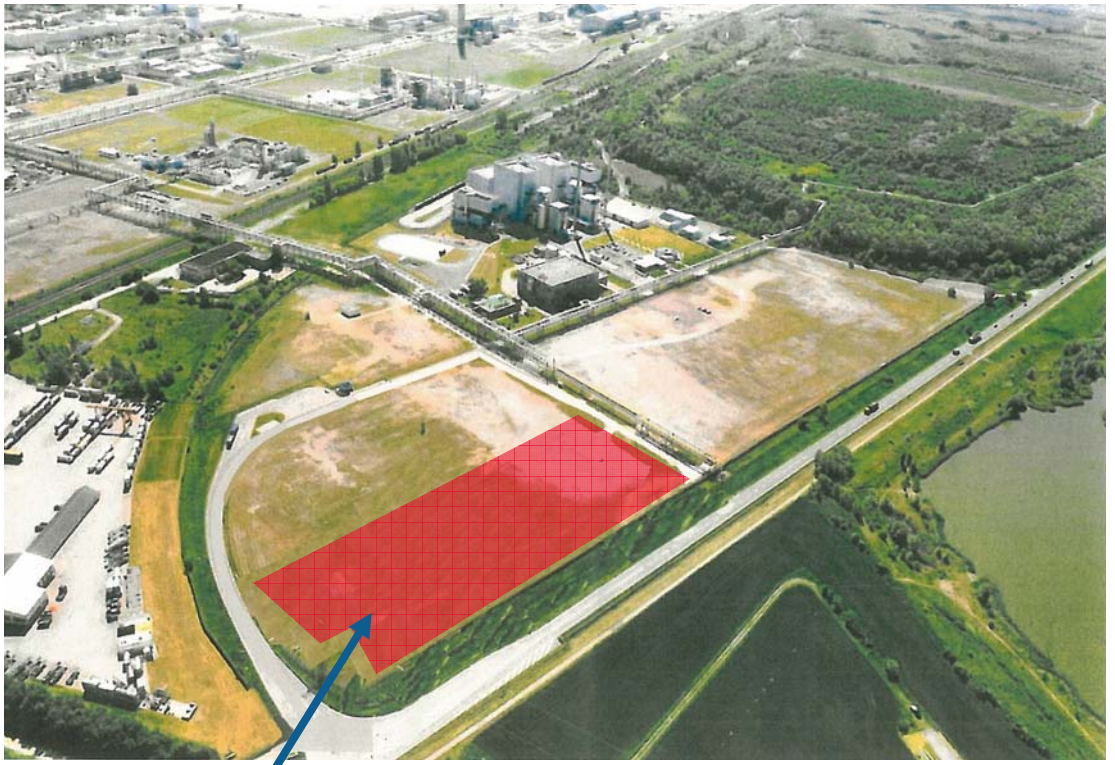


CBP Leuna
The first investigated Processes



- 1: Innovative Enzyme Processes
- 2: Lignocellulose Biorefinery
- 3: Innovative Fermentation Processes
- 4: Micro Algae, Greenhouse, Downstream
- 5: Bio-Ethylene and Biogas
- 6: Office, Utilities and Store
- 7: Possibility for Extension

CBP Leuna:
Location at Industry Park Leuna



CBP

CBP Leuna:
Location at Industry Park Leuna

A promising example: Bio-Ethylene for Biorefinery

Mega plants

1 m t/a Ethylene

~ 1 bn € investment

~ 1,000 €/t (pipeline)

Bio-Ethylen

5 - 100 kt/a Ethylene

and in between?

approx. 1,400 €/t

(on-site production)

@ 30 – 50 kt/a plant

Container & Cylinder

< 1 kt/a Ethylene

+ liquefaction/filling (300 €/t)

+ transport (400 €/t)

~ 1,700 €/t (truck transport)

Bio-Ethylene Market: Promising Development

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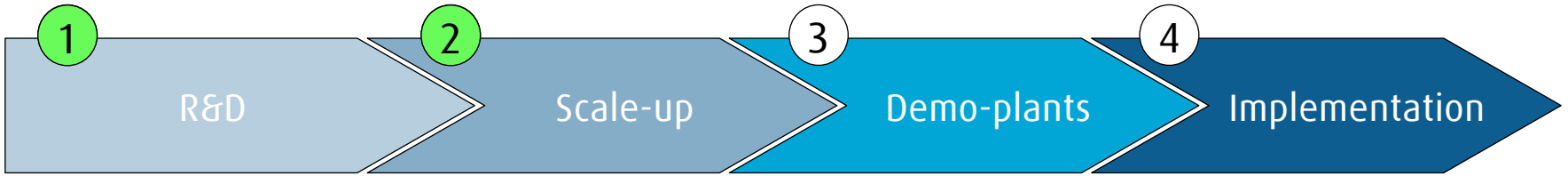
— Customer pull (Coca-Cola, Pepsi, Heinz, Volvic, Procter & Gamble, etc.)
— Green image towards end-users
— Value-added for ethanol (first commercial plants based on 1G ethanol operating)
— Linde activities ongoing with Partners (medium scale, plants based on 2G ethanol)

The Linde Involvement in Process Implementation

Development, improvement of processes

- Industrial collaborations
- Collaborations with universities, Fraunhofer
- Government funded projects (national/international)



Scale-up of processes from lab to pilot size

- General contractor and partner of Fraunhofer CBP*
- Linde pilot plants

* Center for the development of chemical- and biotechnological processes - CBP

Scale-up of Processes from Lab to Pilot Scale
"Green" Hydrogen via pyro-reforming of Glycerol: a new Linde Pilot-plant in Leuna

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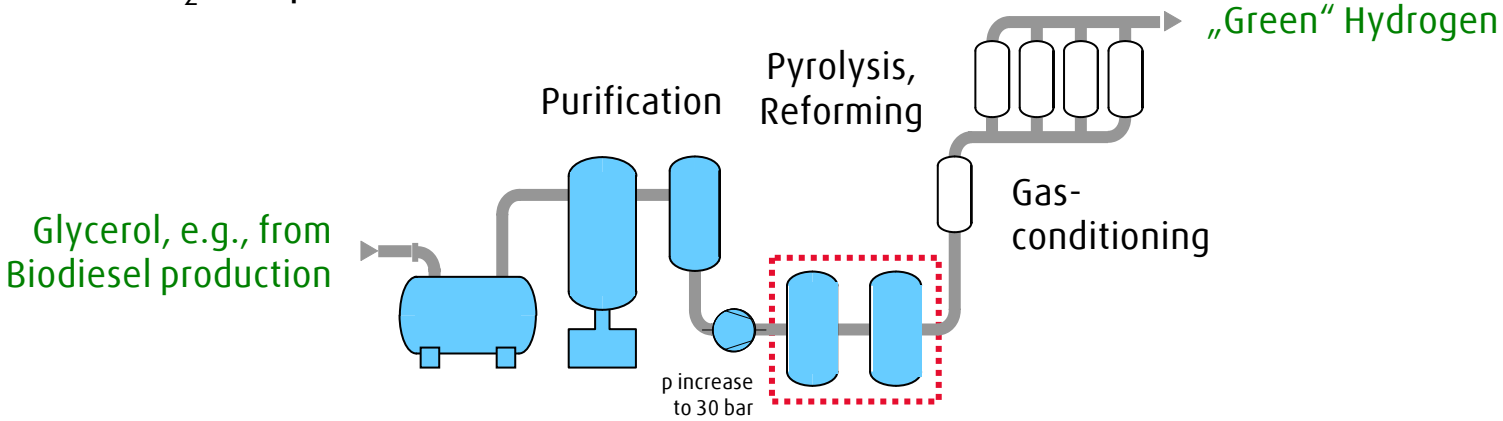
- Cost-competitive technology to produce "green" hydrogen
- Takes advantage of existing Linde technologies
- Possibility of other biogenic feedstocks (tests ongoing)
- Successful start-up of pilot plant Q2/2010
- Capacity approx. 400.000 Nm^3/year[1)]
- Approx. 140 kg H_2/t Glycerol
- Sustainable CO_2-footprint[2)]



1 After water gas shift, prior to pressure swing adsorption
2 According to "RICHTLINIE 2009/28/EG DES EUROPÄISCHEN PARLAMENTS UND DES RATES vom 23. April 2009"

Source: Dr. Hubertus Winkler, Linde R&D

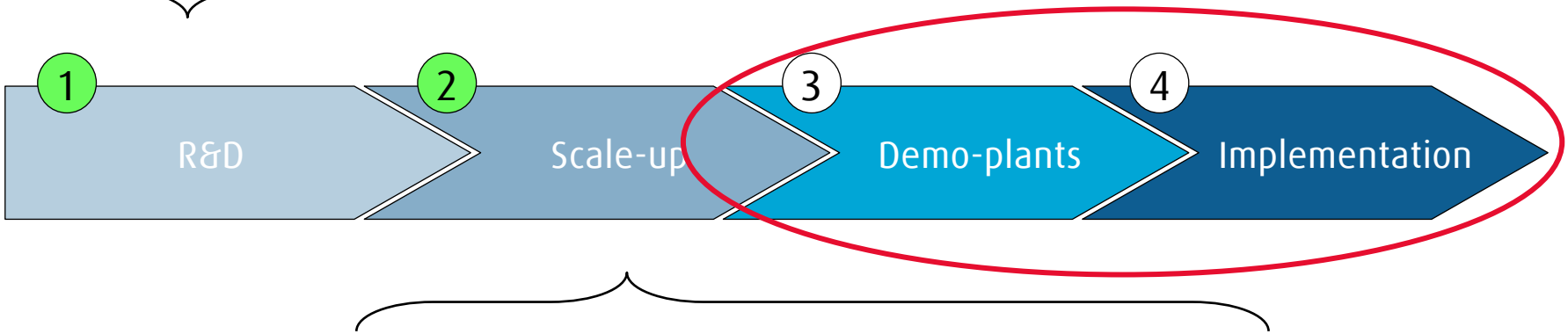
Pyro-Reforming – Glycerol pilot unit

Next Steps Towards Bio-based Chemicals

Development, improvement of processes

- Industrial collaborations
- Collaborations with universities, Fraunhofer
- Government funded projects (national/international)

Ongoing activities together with partners



Scale-up of processes from lab to pilot scale

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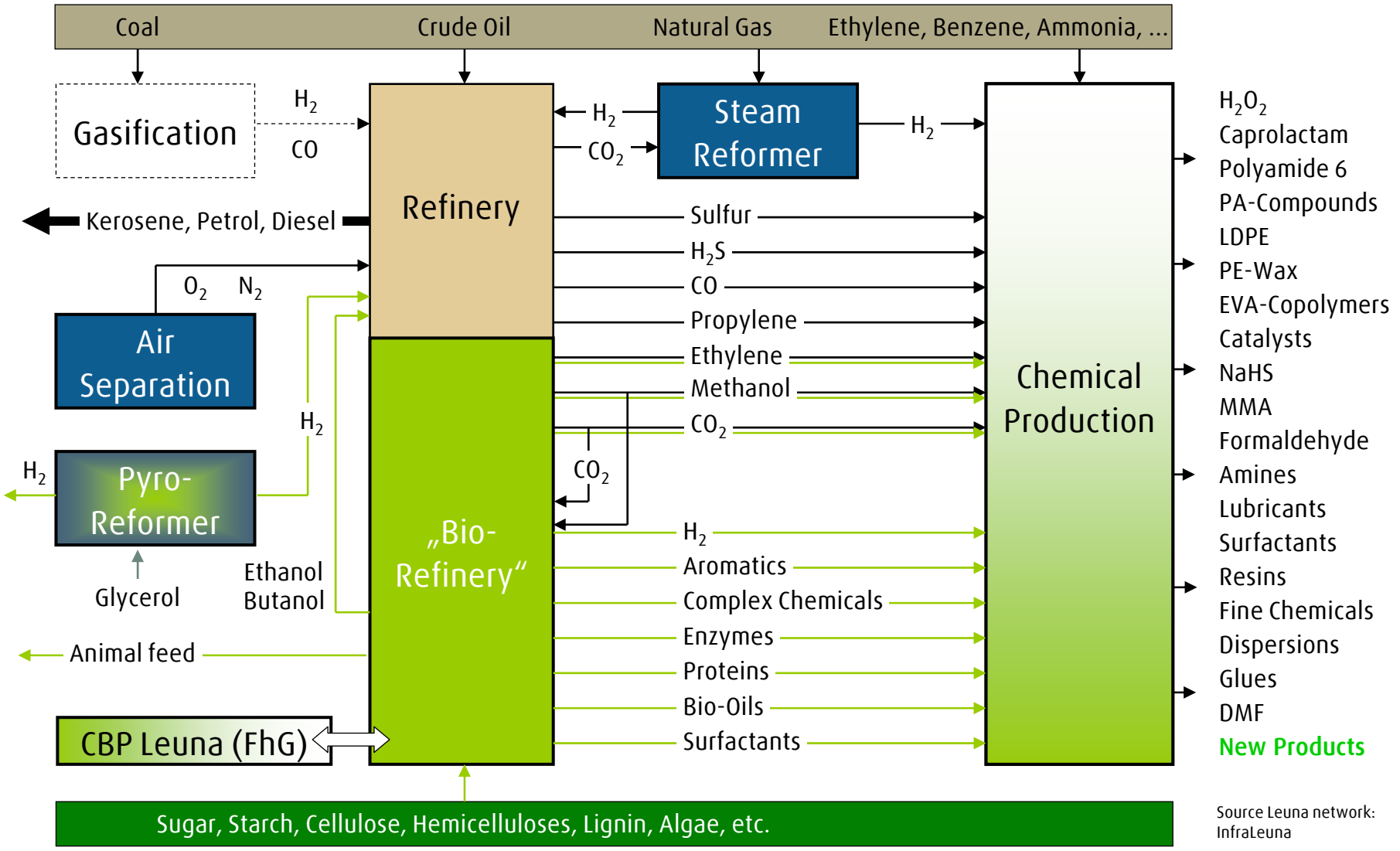
Model for an Integrative Site Concept – Outlook „Biorefinery Leuna“



Source Leuna network: InfraLeuna

Conclusion & Outlook

Trend - from "1G reality" to integrated next generation biorefining

Challenge:

- from established mature technology with easy-to-process food & feed raw materials and well-known products
- via emerging technologies under development
- via difficult-to-process LCB raw materials
- to established or novel products

Preferred short to midterm solution:

Integrative bio/chemical "Verbund" concepts tapping the full synergy potential of existing sites

Thank you for your interest.

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